April 10th

18:00-21:00 Welcome at CosmoCaixa

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April 11th

Auditorium

09:00-09:30 Opening

09:30-11:00 Critical State Memorial
Chair: A. Campbell

"The critical-state seen by magneto-optical imaging"

Tom H. Johansen
Department of Physics, University of Oslo, and Centre for Advanced Study at the Norwegian Academy of Science and Letters, Oslo, Norway.

Magneto-optical imaging (MOI) allows direct visualization of magnetic flux, and with its very high spatial and temporal resolution it provides invaluable experimental knowledge about the electromagnetic response of superconductors. During the last decades MOI has contributed vastly to reveal the flux penetration behavior in thin superconductors, where theoretical modeling of the critical-state was largely delayed compared to the bulk case, due to the non-local electrodynamics in thin samples placed in a perpendicular field. The great work of E. H. Brandt and others to model the flux- and current-distributions in the transverse geometry was largely inspired by MOI experiments. The MOI technique has also been instrumental in discovering conditions when the critical-state becomes unstable. Highly dramatic phenomena such as the flux fingering (dendritic) instability, macro-turbulence, and the recently found quasi-1D flux avalanches occurring in films grown on vicinal cut substrates, are examples that will be presented and discussed.

"Electric Field Formulation for Thin Film Magnetization Problems"

Leonid Prigozhin[1], J W Barrett[2]
[1]Ben Gurion University, Israel. [2]Imperial College, London, UK

Existing variational formulations of the critical state models are useful for computing the magnetic field and current in type-II superconductors of different shapes. However, the electric field, which determines the distribution of energy dissipation in a superconductor, is typically excluded from these formulations and remains unknown. Replacing the critical state current-voltage relation by a power law only partly resolves this difficulty: if the power is high, even small errors in current density lead to unacceptable errors in the electric field. Several

approaches for determining the electric field in long cylinders, both in parallel and perpendicular external fields, have recently been proposed for the critical state models.

For thin film magnetization problems determining the electric field is of especial interest. We present a new mixed variational formulation of these problems, written for two variables: the electric field and an auxiliary scalar magnetization function. Our numerical algorithm, based on this formulation, uses the Raviart-Thomas elements to approximate the electric field and piecewise linear elements for the magnetization function. The method suffers no accuracy loss of the computed electric field even for very high powers in the power law model and, therefore, is applicable also for the efficient solution of thin film critical state model problems.

"50 years of critical-state: a historical view "

A. Sánchez
Grup d'Electromagnetisme, Departament de Física, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Catalonia, Spain

In this talk, we will give a brief journey through the 50 year-history of the critical-state model, from the original paper by Charles Bean in 1962 to the present. A (non-exhaustive) list of seminal papers will be presented along with the main developments. In the talk we will also take a look at the scientists that made these works possible.

11:00-11:30 Cofee Break

11:30-13:30 Critical State session , Auditori Hall
Chair: A. Morandi, A. Stenvall

"Electromagnetics close beyond the critical state: thermodynamic prospect"

A. Badía[1], C. López[2]
[1]University of Zaragoza, [2]University of Alcalá de Henares, Spain

In type-II superconductivity, the critical state concept traditionally applies to electromagnetic processes that occur at de nite values of the current density $J = Jc$. *In its simplest expression (1D problems), this means* $|J| = \pm Jc\ (or\ J \in \{-J_c, J_c\})$. *More generally, one speaks about* J_c *belonging to some critical surface* $Jc \in \partial\Delta$ *that is the boundary of a set of allowed values. From a basic point of view, the condition of criticality is, in fact, a consequence of Faraday's law together with a material law of the kind* $|J| \leq J_c\ (or\ J \in [-J_c, J_c]\ in\ 1D)$. *Physically, it is said that a maximum retaining force on the magnetic vortices allows a maximum circulating current, whereas this specific value eventually appears due to the electromagnetic induction law.*
Since the seminal work by Bean, a huge number of experimental data have been successfully analyzed under the above scenario of criticality. However, it is apparent that magnetic flux penetration has to take place as an avalanching process when the threshold condition is exceeded. Typically, one argues that magnetic diffusion occurs so fast that the superconductor instantaneously jumps from one critical state to the other when going resistive.

In this contribution, we will argue that the critical states may be interpreted as metastable limits of nonlinear diffusion processes. More specifically, we show that for small excursions beyond the critical condition, one eventually obtains the critical state model predictions from a convergent sequence of relaxing profiles. Adopting a thermodynamic formulation, the concept will be applied to generalized situations in which different physical conditions are imposed on different components of the current density. The theory is formulated so as to incorporate anisotropic behavior, both for the critical current ow and for the material resistivity. Several examples will be provided to allow comparison of our diffusion sequences and their convergence to critical state results. In particular, the tape geometry will be explored for several experimental conditions.

"AC losses in thin coated conductors under non-sinusoidal conditions"

V. Sokolovsky[1], L. Prigozhin[2], M. Spector1, V. Meerovich[1]
[1]Physics Department, Ben-Gurion University of the Negev, POB 653 Beer-Sheva, Israel
[2] Department of Solar Energy and Environmental Physics, Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus 84990, Israel

AC losses in superconducting wires and tapes are usually studied for applied sinusoidal currents and/or magnetic fields. However, currents in electric power systems contain a variety of harmonics. We solved analytically and numerically, in the infinitely thin approximation, the transport current and magnetization problems for coated conductors under non-sinusoidal conditions. The analytical expressions for eddy-current and hysteresis losses have been obtained in the framework of the critical-state model neglecting response of the normal-metal substrate and stabilization layers. The contribution of higher harmonics to losses per cycle is determined by both their phase shift relative to the main harmonic and amplitude. It has been shown that the 5% third current harmonic (for the phase shift π) increases eddy losses in the normal-metal parts by up to 90% at a transport current close to the critical value.
Numerically, for the power-law current-voltage characteristic of a superconductor, the contribution of higher harmonics to the total losses in a coated conductor was investigated in a wide range of the power index. It has been shown that even at a low power index (n = 4) the contribution of a 10% third harmonic can reach 44% of losses caused by the main current harmonic. For high external magnetic fields an approximate analytical solution has also been derived and compared to the numerical solution.

"Fast simulation method for optimisation of real-size superconducting windings"

E. Pardo
Institute of Electrical Engineering, Slovak Academy of Sciences, Bratislava, Slovakia

AC loss in superconducting windings degrades the efficiency of AC devices, difficultates cooling and, in DC magnets, limits the ramp speed. Many applications contain windings with many turns, of the order of thousands. In order to design the cryogenic system and reduce the AC loss, it is necessary to develop numerical methods for large number of turns. In this contribution, we present a numerical method to obtain the turn-by-turn AC loss in coils with virtually any number of turns, regardless of their magnitude. The model assumes the sharp E(J) relation for the critical state model. Its only input is the anisotropic field dependence of the critical current density. Regarding each turn, the model takes into account the hysteresis current distribution in the neighbouring turns up to a certain distance. We apply this model to optimise the dimensions of several solenoids and stacks of pancakes regarding the AC loss and the critical current. In particular, we show the feasibility of the model for stacks of 32 pancakes

and 200 turns each. We found that ignoring the hysteresis in the neighbouring turns results in an unacceptable error, except for closely packed coils with both thickness and height much larger than the tape width. In addition, the geometry with maximum generated field are for relatively sparse coils. The optimum quality factor (average magnetic energy over dissipation) is for coils even sparser. In conclusion, optimising the coil geometry by simulations may increase the maximum generated field and greatly reduce the AC loss.

“Applicability of the adaptive resistivity method to describe the critical state of complex superconducting systems”

S. Farinon[1], P. Fabbricatore[1], F. Grilli[2], P. Krüger[2]
[1]INFN - Sezione di Genova
[2]Karlsruhe Institute of Technology, Institute for Technical Physics, Hermann-von-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen, Germany

The adaptive resistivity method is a special algorithm which allows approaching the Bean critical state by an iterative adjustment of the material resistivity and can be quite easily implemented in commercially available finite element codes. Its main advantage is that the critical state model does not depend on time (or frequency of the applied loads) so that the critical state description is uniquely determined by the field profiles at the peak value of the applied loads. We proved its validity in the description of complex superconducting systems comparing its results with the wellknown edge-element model based on direct magnetic field formulation.

“Modelling the control of magnetic fields with superconductor-metamaterial hybrids systems”

Carles Navau[1], Jordi Prat-Camps[1], Alvaro Sanchez[1], Fedor Gömöry[2], Mykola Solovyov[2], Ján Souc[2].
[1]Grup d'Electromagnetisme, Departament de Física, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Catalonia, Spain
[2] Institute of Electrical Engineering, Slovak Academy of Sciences, Bratislava,

In this work we present the antimagnet, a design that conceals the magnetic response of a given volume from its exterior, without altering the external magnetic fields. As it leaves the external fields unperturbed neither the content inside the antimagnet nor the own antimagnet can be magnetically detected from the outside, enabling the "magnetic invisibility" of a given region. In addition, different from other proposals, materials involved in the present design are already technologically and scientifically available; this makes the antimagnet design a feasible possibility to be experimentally implemented.
Our design is composed of only three kind of materials. A first interior layer is made of ideal superconducting material ($\mu_{SC} = 0$), surrounded by a series of alternating layers of two types. A-type layers are made of ferro (para)-magnetic homogeneous isotropic material with a constant permeability ($\mu_A > 1$) and R-type layers are characterized with an homogeneous and anisotropic permeability, with a radial permeability between 0 and 1 ($1 > \mu^{\rho}_R > 0$ and $\mu^{\Phi}_R = 1$).
The global effect of the device interacting with static magnetic fields is simulated using finite elements commercial software (COMSOL Multiphysics) as a function of the total number of layers and the externally applied magnetic field. The design we propose may have relevant applications in enabling patients with peacemakers or magnetic implants to use medical equipment based on magnetic fields (such as MRI) or in reducing the magnetic signature of vessels and planes.

13:30- 15:00 Lunch & networking and Museum visit

15:00-16:30 Finite Elements I , Auditori Hall
Chair: E. Pardo , A. Badía

"Simulation studies on the magnetisation of (RE)BCO bulk superconductors using various split-coil arrangements"

Archie M. Campbell[1], Zhihan Xu[1], Richard Lewin[2], David A. Cardwell[1] and Harry Jones[2]
[1] Bulk Superconductivity Group, Department of Engineering, University of Cambridge, Trumpington Street, Cambridge, CB2 1PZ, UK
[2] Magnet Development and Applied Superconductivity Group, Department of Physics, University of Oxford, Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, UK

Simulation studies were conducted on the magnetisation of (RE)BCO bulk superconductors using various split-coil arrangements by solving the critical state equation using commercial software FlexPDE. A pair of coaxial coils of identical size is identified as an optimum arrangement for practical magnetisation at 77 K by the 'zero field cooling' technique. In general, the magnetisation process is likely to be most effective when the outer radius of the coils lies between 100% and 50% of the sample radius. A relatively large coil pair is necessary for samples with either a smaller aspect ratio or larger values of Jc0. Two different regimes of flux penetration are found to be involved in the magnetisation process. For a sufficiently small sample, the penetration field is determined by flux propagation from beneath the coil to the centre of the sample; for a sufficiently large sample, the definitive propagation route is from beneath the coil to the periphery of the sample. Effective split-coil magnetisation occurs only in the former regime, and both penetration regimes are completely different from that involved in the solenoidal-coil magnetisation process.

"Modelling self-field hysteresis losses of helicoidal structures in two dimensions with finite element method"

A Stenvall[1], M Siahrang[2,3], F Grilli[4] and F Sirois[2]
[1] Electromagnetics, Tampere University of Technology, P.O. Box 692, FIN-33101 Tampere, Finland
[2] École Polytechnique de Montréal, Montréal, QC H3C 3A7, Canada
[3] Currently with Safe Engineering Services & technologies Ltd., Laval, QC, H7L 6E8, Canada
[4] Karlsruhe Institute of Technology, Institute for Technical Physics, Hermann-von-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen, Germany

The principles of the effect of twisting conductors for the reduction of the coupling losses are well understood. However, there is generally not much knowledge on how the self-field hysteresis losses change due to the twisting. The main reason for this is that the two dimensional approaches that the typical hysteresis loss computations take have not thus far been taken to the level that the twisting could be included in the model. Only recently some numerical codes have appeared to also consider the effect of twisting in continuous

symmetries. For general three dimensional simulations, one big problem is that no robust, widely accepted, and easy to obtain model for the relation between current density and electric field is available. On the other hand, helicoidal structures can be approximated by assuming currents along the helical trajectories. However, this approximation is probably realistic only for high aspect ratio conductors such as YBCO coated conductors since some three dimensional simulations suggest that currents do not follow helicoidal lines in twisted conductors in self-field. Anyhow, the approximation justifies the utilisation of the power-law for superconductor resistivity and thus makes eddy current approach toward solution of a hysteresis loss problem feasible. In this paper we utilise a finite element method model for eddy current problems of helicoidal structures. The model uses the full three dimensional geometry but allows discretisation in a two dimensional domain. We embed into this model
a non-linear power-law for modelling the conductor's resistivity and study how the self-field losses are influenced by the twisting. Additionally, we compare the model in case of high aspect ratio conductor to 1D code which utilized integral equation method and is designed for simulating twisted single layer 2G superconducting power cables. Finally, we discuss on modelling problematics and present some open questions related to modelling such a configuration and AC-loss computations in three dimensions.

"Eddy-Current Formulations for Superconductor Hysteresis Loss Modelling"

Valtteri Lahtinen and Antti Stenvall
Electromagnetics, Tampere University of Technology, PO Box 692, 33101 Tampere, Finland

Using non-linear resistivity, the superconductor hysteresis loss modelling problem may be formulated as an eddy-current (EC) problem. We discuss three EC formulations suitable for modelling of superconductor hysteresis losses. Namely, the a-v-j-, T-φ- and h-formulation are briefly presented. Through computation results and some theory, the properties of these formulations are discussed and their suitability for different modelling situations is compared. Special attention is paid to h-formulation. We show how an h-formulation based EC solver behaves in so called AC-AC cases, when Dirichlet's boundary conditions for the magnetic field intensity do not correspond to the net current conditions given for the conductors in the computation domain.

"3D simulation of Roebel cables"

Víctor M.R. Zermeño[a], Francesco Grilli[b], Frederic Sirois[c]
[a]Technical University of Denmark, Kgs. Lyngby, Denmark
[b]Karlsruhe Inst. of Technology, Karlsruhe, Germany
[c]Ecole Polytechnique de Montreal, Montreal, QC, Canada

Roebel cable modeling and simulation has proven to be cumbersome. Its true 3D structure does not allow for dimensional reduction by means of symmetries. Several 2D approaches and one 3D model relying upon the infinitesimally thin approximation of the conductors have already been presented. However until now, no full 3D model has been reported. In this work we present a fully three dimensional model of a ROEBEL cable with 14 strands. The model is based on the magnetic field H-formulation. The discretization is made using a mesh with tetrahedral elements and vector interpolating basis functions. Although, the periodicity of the cable structure is used to reduce the model size, no further simplification is made as to keep its 3D features. Plots for magnetic field, current density and AC losses are presented for the case of transport current. Beyond the importance of simulating the ROEBEL topology, this works represents a further step into achieving 3D simulation of superconducting devices at affordable computational costs and memory requirements.

16:30-17:00 Cofee Break

17:00-18:45 Finite Elements II , Auditori Hall
Chair: F.Gömöry, S. Farinon

"Flux pumping, fluctuations and forces"

T. A. Coombs
Cambridge University Engineering Department

This paper describes the behaviour of bulk superconductors when subjected to a varying magnetic field. A magnetic model is described together with experimental results which explain and describe the behaviour of superconducting bulks when subjected to varying magnetic fields. We demonstrate how the behaviour is dependent on the magnitude and period of the perturbations in the fields. The model which we use is an extension to a model originally described in [1] has been implemented in Matlab using the Comsol™ pde solver. A fully integrated model it uses a variable heat source to regulate the magnetic circuit and thereby to achieve flux pumping. Comsol™ is used for post solution visualisation and the model is presented alongside experimental results which support and confirm the conclusions from the model.

"Magnetic shielding properties of a cut superconducting hollow cylinder : modelling and experiment"

P. Vanderbemden, B Vanderheyden
Department of Electrical Engineering and Computer Science, Montefiore Institut, University of Liege, Belgium

This communication deals with the magnetic properties of bulk high temperature superconducting cylinders used as magnetic shields. We investigate, both numerically and experimentally, the magnetic properties of a hollow cylinder with an axial slit along the length of the cylinder which completely cuts the cylinder in half. Finite Element Method (FEM) modelling has been used with a three-dimensional geometry to help us understanding how the superconducting currents flow in such a cut cylinder, and therefore how the magnetic shielding properties are affected, depending on the magnetic field orientation. Modelling results have shown that the slit blocks the shielding currents flow and acts as a "channel" for the magnetic flux lines to enter in the cylinder. The magnetic shielding properties under transverse DC magnetic fields are also measured at the liquid nitrogen temperature (77 K) on a bulk Bi-2212 hollow cylinder. The sample is subjected to a transverse magnetic field whose the direction is varied between 0° and 90° with respect to the cut plane. Both modelling and experimental results point out a strong reduction of the magnetic shielding efficiency when the angle between the applied transverse magnetic field and the normal to the slit plane exceeds 15°.

"Transient state modeling in HTS using ANSYS APDL"

M. Stepien,
Silesian University of Technology, Gliwice, Poland

Modeling of transient state in superconductors, also in HTS is an extremely difficult task. Strong nonlinearities and significant differences of dimensions (e.g., the ratio of the thinnest part to the thickest part is as ~ 1:40) make that FEM calculations need proper procedures and tools to obtain correct results. These difficulties can be solved in different ways, i.e., by developing own software basing on proper formulas of superconductivity or by using commercial FEM software with additional procedures related to superconducting properties. Unfortunately, not every commercial software allows for to applying additional procedures necessary to calculate superconducting properties.
The aim of the presented paper is to discuss possibilities of application of the commercial ANSYS software in computations of transient state of superconductor using built-in standard procedures and intrinsic ANSYS Parametric Design Language (APDL) to adapt software in order to include superconducting properties. The calculations will be presented using quench phenomenon in 1G HTS tape as an example.
ANSYS is suitable to calculate coupled electrical-thermal (and/or mechanical) problems because of dedicated tools in the range of any sort of analysis (steady-state, harmonic and transient). It directly includes dependence of material parameters on temperature. Calculations are based on A-V formulations. Power law dependence is included by dedicated APDL procedures.
An advantage of ANSYS software is the modular structure of calculation procedure and possibility to include all needed properties of materials and mutual physical dependences in sequential coupled analysis.
Final paper will include description of methodology of FEM analysis of concerning phenomena that take place in superconductors. Then illustrative example problem will be discussed embracing geometry of tape, its material parameters and operational conditions. The advantages and drawbacks of the presented methodology will also be presented. Finally short discussion of using ANSYS in other problems of HTS modeling will be included.

"Frequency Domain Computation of Eddy Currents in Superconductors"

S. Mezani, B. Douine, T. Lubin, K. Berger, J. Lévêque and A. Rezzoug
Université de Lorraine - Laboratoire GREEN
Faculté des Sciences et Technologies 54506 Vandoeuvre-lès-Nancy France

The concept of effective resistivity in electrically non-linear media is used to treat problems expressed in terms of phasor quantities under a sinusoidal time varying excitation. 2D and 3D computations of the magnetic field in High Temperature Superconductors (HTS) is carried out using an A-V formulation. Results of ac loss computation in an HTS tube under self field conditions are presented and discussed.

"New progress of finite element modeling for 2G HTS coils"

Min Zhang
University of Cambridge

In this presentation, we present our latest progress of 2G HTS coils modeling using H formulation and finite element software. Both pancake and racetrack models have been well developed in the software of COMSOL. We proposed a new method to take into account of 2G tape anisotropy, and use the model to study the critical current and AC loss of 2G HTS coils. The modeling results are very consistent with experimental measurements. The ac losses calculated *by our model are within 25% error from the experimental measurements using both electric method and boil off method. Employing the coil model, we found that the widely used 100uV/m criterion is too high to determine the critical current of coils. Instead, we proposed a new criterion to determine the critical current of 2G HTS coils, which can promise a long term operation of the coils (Details information can be found in our latest paper to be published in Journal of applied physics).*

"Simplified local model for the mechanical interaction between a finite magnet and a superconductor in the Meissner state"

Efren Diez-Jimenez[1], Ignacio Valiente-Blanco[1], Juan Carlos Garcia-Prada[1] and
Jose Luis Perez-Diaz[2]
[1] Mechanical Engineering Department. Universidad Carlos III de Madrid. Butarque, 15. E28911 Leganes. Spain.
[2] Instituto Pedro Juan de Lastanosa. Universidad Carlos III de Madrid. Butarque, 15. E28911 Leganes. Spain.

A general local model based on London's and Maxwell's equations has been developed to describe the mechanics of the superconductor-permanent magnet system. Due to its differential form, this expression can be easily implemented in a finite elements analysis (FEA) and, consequently, is easily applicable to any shape of superconductor in the Meissner state. It can solve both forces and torques.
This paper reports different experiments undertaken in order to test the model's validity. The vertical forces and the self-alignment angle between a magnet and a superconductor were measured and a positive agreement between the experiments and theoretical calculations was found.

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April 12th

Àgora Hall

09:00-10:45 Devices session , Àgora Hall
Chair: T. Coombs, V. Sokolovsky

"Inhomogeneity Effects in HTS Coated Conductors Used as Resistive FCLs in Medium Voltage Level Grid"

Daniele Colangelo and Bertrand Dutoit
École Polytechnique fédérale de Lausanne

For Resistive Fault Current Limiters (RFCLs) based on high temperature superconducting coated conductors (HTS-CCs), inhomogeneity, in terms of critical current and geometrical imperfections such as stabilizer and substrate thicknesses, plays a very important role and it may actually limit the penetration of such devices on the electrical market. This paper presents an electro-thermal model, developed in SimPowerSystem™, able to describe the transient

respond of HTS-CC candidates with different degrees of inhomogeneity, both in terms of critical current and of thickness stabilizer. Critical current inhomogeneity has been modeled with Gaussian distributions. Layers thicknesses used in the simulations have been chosen by fitting the temperature dependence of tape resistances. Our approach considers relative inhomogeneity positions as well as thermal conduction along the HTS-CC length. The model is tuned using experimental measurements made on REBaCuO coated conductors. A new dynamical thermal calibration of the model is proposed using finite element method calculations. Inhomegeneity effects with different possible faults (e.g. three phases and single phase short-circuit) are presented.

SIMULINK model of free-stabilized, externally-shunted 2G superconducting tapes for SFCL applications

Alfredo Álvarez, Pilar Suárez, José-María Ceballos, Belén Pérez and Fátima Méndez
Lab. of Electrical Application of Superconductors. University of Extremadura. Spain

The first characteristics looked for in resistive Superconducting Fault Current Limiter (SFCL) elements are high resistance in normal state operation and good stability after transitions. This latter means that the elements recover their superconducting properties without degradation or damage when they return to the superconducting state after the fault has cleared.
The stabilizer in 2G superconducting tape consists of conducting layers (copper or stainless steel usually) that permit shunting of part of the current when the total transport current in the tape exceeds the critical current in the YBCO superconducting layer. But, while this provides stability, it reduces the resistance of the tape in normal state operation since the conducting layers are in parallel with the YBCO layer.
In order to attain a good relationship between the YBCO layer normal state resistance and the resistance of the shunt, a free-stabilized, externally-shunted 2G superconducting tape was modeled with a SIMULINK application controlled by MATLAB. Some of the parameters of the superconducting layer model have been estimated by mean of experimental tests, and the other materials, taken out in the program libraries.

"Design optimization and prototype fabrication of HTS magnets"

C. Boffo, P. Revilak, J. Steinmann, W. Walter, I. Wirth
Babcock Noell GmbH, Alfred-Nobel-str. 20, 97070 Würzburg, GERMANY.

The engineering current density and the single piece length of commercially available 2nd generation HTS conductors are rapidly improving making them more and more attractive for commercial applications in particular when adopted in conjunction with conduction cooled systems.
Babcock Noell GmbH (BNG) successfully fabricated a first HTS undulator short prototype demonstrating that the technology is mature enough to compete with LTS at temperatures close to 4.5K. Here we focus on the modeling approach adopted for small coils fabricated as part of an R&D program aiming to further extend the company experience on HTS technology.

"Finite element models for quench behavior of YBCO coated conductors"

Weiyong Li, Jun Zheng, Yijun Dai, Wei Chen, Yong Zhou, Xiaojun Niu
Wuhan institute of marine electric propulsion, 430064, Wu Han, China

Finite element model is built with Ansys software to study the self-field quench behavior of YBCO coated conductors. A heat pulse is introduced into the tape to initiate a normal zone.

Then time-dependent electric field and temperature in the tape are caculated through the coupling field method of electric and thermal. With these datas, minimum quench energy and normal zone propagation velocity are computed as a function of transport current. These results are also compared with the measured data in other author's work, they fit very well. This model offers a very convenience tool to study the quench behavior of YBCO coated conductors.

"Designing a Shielded-Core Superconducting Fault Current Limiter using Finite Element Analysis"

Lukas Graber[1], Tim Chiocchio[1], Jozef Kvitkovic[1], Michael Steurer[1], Sastry Pamidi[1], Alexander Usoskin[2]
[1]Center for Advanced Power Systems, Florida State University, Tallahassee, FL, USA
[2]Bruker Energy & Supercon Technologies, Bruker HTS, Alzenau, Germany

A superconducting fault current limiter (SFCL) is a device to be used in electric power systems to limit the magnitude of fault currents in the event of a short circuit. SFCLs are expected to be particularly useful in power grids with ever increasing levels of fault currents, primarily due to increases in power generation capacity and, particularly at the distribution level, the observed increase in penetration of local power generation provided via rotating machinery. Currently, various designs of SFCLs are under development. Among the different types of SFCL, the inductive SFCL is especially interesting since it is expected to have significant operational advantages stemming from its design features [1]. The inductive SFCL does not need current leads and hence does not have the heat leak from the ambient space and Joule's heating from the current leads. This significantly lowers consumption of the liquid nitrogen (LN2) compared to other types of SFCLs.

Figure 1 depicts the basic conceptual design of a shielding-core SFCL, which is a particular type of inductive SFCL. The primary coil is connected electrically in series with the load impedance ZLoad. In normal operation, the superconducting (SC) rings shield the magnetic core inside the primary coil by carrying a counter-acting current, thereby reducing its inductance (Figure 2 left). In a fault condition, the increasing current in the primary coil causes a corresponding increase in the magnetic field at the SC rings (Figure 2 right). The superconductor can only shield the magnetic field up to a certain value at which it quenches to the normal state. This transition significantly increases the inductance of the primary coil and thus limits the current in the external circuit (i.e. the power grid).

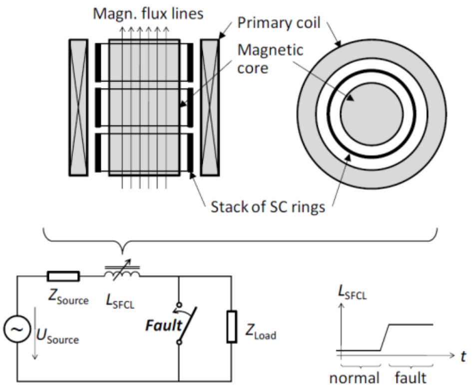

Figure 1: Schematic drawing of the shielding-core type inductive superconducting fault current limiter (top) along with the electric circuit in which it is embedded (lower left) and a graph showing the idealized change of the primary inductance (lower right)

Last year, a first design of a benchtop demonstration module of an inductive SFCL without iron core and based on a single HTS ring was modeled using COMSOL Multiphysics 4.2 [1]. The model was validated by an experiment. Currently, a bigger SFCL, based on a stack of multiple HTS rings and an iron core is in the design phase. A finite element analysis (FEA) model serves to optimize its primary design parameters such as the number and arrangement of superconducting rings and the number of turns of the primary *coil. This benchtop SFCL is planned to be embedded in a simulated power system using the power hardware in the loop (PHIL) concept. A real time computer simulator reads the voltage across the primary coil and imposes the current from the simulated power grid onto the SFCL, thereby facilitating the dynamic interaction between the SFCL and the simulated power grid by means of a power amplifier. Similarly, the 2D axisymmetric FEA model, based on the fully-transient magnetic field equations is embedded into a lumped element circuit simulation. The circuit determines the current in the primary coil, whereas the FEA calculates the inductance of the coil. These two parts of the model are two-way coupled. The model is expected to yield to a better understanding of the electromagnetic behavior of the SFCL and help with optimizing its design for applications in terrestrial or shipboard power systems.*

10:45-11:15 Cofee Break

11:15-13:00 Methods Improvement session, Àgora Hall
Chair: F. Sirois, C. Navau

"Electromagnetic energy flow and dissipation in superconducting coils"

Fedor Gömöry and Enric Pardo
Institute of Electrical Engineering, Slovak Academy of Sciences, Bratislava, Slovakia

The distributions of magnetic field and electrical current in the winding of a superconducting coil for a cyclic excitation can be used to analyze the flow of energy and dissipation in the winding during the cycle. The general method to calculate the dissipation in one cycle is the integration of the product of local current density and electrical field over the cycle duration and all the winding turns. Alternatively, one should find the same result by integrating in time the product of the coil current and the voltage on its terminations. We show that the use of both approaches is a nice tool to study the flow of electromagnetic energy in the coil winding because it allows to compare the evolution of "loss voltage" and the local dissipation in time as well as its distribution in the coil turns. We performed such analysis for coils with circular turns made from coated conductor tapes as well as round wires. The conclusion is that the instantaneous loss power covered by the current source does not necessarily correspond to the instantaneous dissipation in the superconducting winding.

"A novel integral approach to the 2D modeling of superconductors by means of the bounded E-J power law"

Antonio Morandi
University of Bologna, Italy

Numerical modeling is an essential tool for the design and the optimization of practical superconducting devices. The solution of the interior field problem, namely the calculation of the distribution of current density and electric and magnetic field inside the superconductor, is in fact a mandatory step for obtaining a variety of information such as for example AC loss,

levitation force, trapped magnetic field, voltage during over-current, etc., which are of interest for practical applications. Analytical solutions may be obtained for 1D geometries (infinite slabs or cylinders)subject to uniform applied field. In case of actual 2D or 3D geometry and/or non uniform applied field numerical methods are the only possible way for the solution of the field problem.

In order to build up a numerical model the following steps, which are intimately correlated each other, must be accomplished

1. find a suitable constitutive law of the material which relates the local electric field E to the local current density J on a macroscopic scale.

2. find a suitable mathematical formulation of the eddy current problem within the superconductor by introducing, if needed, appropriate potentials in order to represent the field quantities

3. find a suitable algorithm for obtaining a matrix representation of the problem with a finite number of variables

In the present work all these points are discussed in detail. In particular the reasons (both physical and mathematical) why the bounded E-J power law is preferred to the critical state model as a constitutive relation of the superconductor are explained. The role of the electric field and the scalar electric potential for obtaining accurate results in practical operating conditions is pointed out and the limit of calculating the Ohmic loss of a superconductor as hysteresis loss by means of the magnetization loop is quantitatively examined. Furthermore a novel discretization approach for the 2D problem (both with axial and translational symmetry) is introduced. The nodal values of the current density are assumed as state variables of the problem and a piecewise linear space distribution is reconstructed by means nodal shape functions. A method to relax the tangential continuity of the current density at the interface between materials with different physical characteristics is illustrated. The proposed method is proven to converge very fast and to be an effective alternative to the use of circuit models or edge elements for 2D problems involving both homogeneous and composite materials.

"Hybrid model of quench propagation in Coated Conductors"

A. Badel[1], L. Antognazza[1], M. Abplanalp[2], C. Schacherer[2] and M. Decroux[1]

[1]DPMC, University of Geneva, Switzerland

[2]ABB Corporate Research Centre, Dättwil, Switzerland

HTS coated conductors (CC) with very good characteristics are now available on the shelf, with increasing lengths. Their use in large scale applications, such as fault current limiters, motors or high field magnets is widely studied. However, their very low normal zone propagation velocities (NZPV) is a major issue for their survivability under quench conditions.

We developed a 2D/3D electro-thermal model is being developed for a better understanding of the thermal behavior of the different conductor layers. In order to tackle the problems of the very high aspect ratio of such tapes and the stiffness of the transition front, a hybrid approach is being used. It combines analytic calculations and finite element method. The results obtained with the 2D version of the model are compared with experimental data. The influences of the substrate thickness and the interface thermal conductance on the NZPV are studied using this model. The influence of the thermal diffusion in the width of the substrate is also evaluated using 3D simulations.

"A Matlab tool for the determination of current densities in HTS multiseed bulk samples based on sand pile model and genetic algorithms"

João Murta Pina[1], Pedro Pereira[1], José Ceballos2, Alfredo Álvarez[2]
[1] Centre of Technology and Systems, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Monte de Caparica, 2829-516 Caparica, Portugal
[2] "Benito Mahedero" Group of Electrical Applications of Superconductors, Escuela de Ingenierías Industriales, University of Extremadura, Avenida de Elvas s/n, 06006 Badajoz, Spain

Sand pile model is often used to describe single domain HTS bulk samples, which, together with Bean model, consists of a valuable approach in the design of, e.g., electrical machines. In this work, the extension of this methodology to multiseed samples is described, and a Matlab tool to use it is implemented. This tool receives as inputs experimental data, and outputs inter and intragranular current densities, where the identification of these parameters is based on genetic algorithms. The methodology is validated with experimental results and its application to the analysis of an all superconducting linear synchronous motor is exemplified.

"A simulation model of Superconducting Fault Current Limiter"

S. Nemdilli and, S. Belkhiat
Department Of Electrotechnics, Faculty of Engineering, University Of Setif, Setif 19000, Algeria

The development of the power electrical systems is accompanied by the permanent increase of a fault current. The increase of the fault current levels leads to increased adverse effects on the electric power equipment. A superconducting fault current limiter (SFCL) could provide a viable solution to controlling fault current levels in electrical distribution networks. In order to integrate the SFCL into power grids, there is need to conveniently predict the performance of the SFCL in a given situation. Up to now no simulation model of SFCL is validated or introduced in the Library of MATLAB software. In this paper a simulation model for a resistive type superconducting fault current limiter is proposed. The model includes the electric field-current density (E-J) characteristics of High Temperature Superconductors (HTS). For that, a graphical interface using Graphical User Interface (GUI) of MATLB has been developed. This one is flexible and facilitates the introduction and the change of data of SFCL model. The operation characteristics and the behavior of limiter for a resistive SFCL has been investigated. The proposed model can accurately predict the current-time waveforms achievable with typical limiters.

13:00- 14:30 Lunch & networking and Museum visit

14:30- 16:00 Other Methods session, Àgora Hall
Chair: P. Vanderbemden , B. Dutoit

" The straight approximation of the current loop: equivalence between 2D models of superconductor with axial and translational symmetry"

Antonio Morandi
University of Bologna, Italy

2D modeling is widely used for analyzing superconducting systems with axial or translational symmetry. 2D axis symmetric modeling is a self-consistent approach which applies to actual systems with cylindrical symmetry. Rather than introducing any ad hoc assumption it merely represents the actual physics of the problem. 2D translational symmetric modeling instead strictly apply to infinitely long systems which do not exists in reality. Nevertheless this modeling approach is effectively exploited for analyzing practical superconducting systems with "long aspect" by neglecting the edge effect. 2D modeling with translational symmetry also apply to cylindrical systems if the radial extension of the domain is small compared to its average radius.
It must be considered however that the domain under investigation is coupled with an external circuit, which means that a current or a voltage (which may also be zero) due to an external generator is applied to it. A substantial distinction must be made between these two cases however. In particular, care must be taken in evaluating the consistency of the model if 2D systems with an applied voltage are analyzed by means of the translational symmetric approach.
In this paper the formulation of the 2D problem with axial and translational symmetry is reviewed. The equivalence between the two approaches for the modeling of axis symmetric domains with long aspect (i.e. with the radial extension small compared to the average radius) is discussed both for the current driven and the voltage driven case. In particular, the role of the electric scalar potential is analyzed and the importance of correctly choosing which expression of the vector potential is to be used for the axis symmetric and the translational symmetric model in order for the equivalence to hold is pointed out. The limit of applicability of this equivalence, provided that the right choice of the vector potential is made, is also quantitatively discussed.

"Modelling and current distribution computation in HTS samples"

J Amorós[3], X Granados[1], M Carrera[2], T Puig[1], X Obradors[1]
[1] Institut de Ciència de Materials de Barcelona, ICMAB-CSIC, Campus UAB, 08193, Bellaterra, Spain
[2] Dept. Medi Ambient i Ciències del Sòl, Universitat de Lleida, Jaume II, 69. 25001 Lleida, Spain
[3] Dept. Matemàtica Aplicada I, Universitat Politècnica de Catalunya, Diagonal 647, Barcelona, Spain

We discuss our discretization and linearization procedure, which we have applied successfully to the computation of critical current maps from Hall probe measurements of the magnetic field (inverse Biot-Savart problem) on both HTS tapes and bulks. This modelization procedure makes the least possible a priori assumptions about the circulating current: In 2-dimensional samples it will detect any distribution of current (one or several domains, inhomogeneities or

defects). In 3-dimensional samples it will yield the average of the actual circulating current along the c-axis.
It is based on subdivision of the measurement region in a 2-dimensional rectangular grid, homogeneous along the c-axis, and determination of the magnetization on each grid element. In the case of open circuits (such as stretches of tape), we provide a suitable completion of the discretization grid so that the magnetization and current map on the open circuit can still be reliably determined.
Application to magnetization of the samples under applied external fields and self field state measurements are analized and discussed. This discussion is illustrated with inverse Biot-Savart computations on both simulated and real samples.

"Analytical Modeling of Bulk Superconductor in a Coil"

K. Berger, T. Lubin, S. Mezani, J. Leclerc, J. Lévêque
GREEN, Université de Lorraine, Faculté des Sciences et Technologies, BP 70239, 54506 Vandoeuvre-lès-Nancy, France

An analytical computation of the magnetic field distribution around a superconductor bulk pellet inside a coil is proposed. The superconductor is considered as a perfect diamagnetic material under zero-field cooling condition, i.e. the magnetic vector potential is equal to zero inside. The proposed analytical model is based on the resolution of Laplace's and Poisson's equations by the separation of variables method for each subdomain, i.e. coil winding and air-gap between pellet and coil. The boundary and continuity conditions between subdomains yield to the global solution. Magnetic vector potential, magnetic field distributions, and the force on the bulk pellet are computed by the analytical method. They are also compared with those obtained from finite element analysis and experiment. Other types of problem that can be solved with this method and possible issues will be also presented.

"Electrodinamics of isotropic superconductors"

Klimenko, E.Yu.
JSC Industry Group "Novik"

A nonlinear conductivity tensor $\sigma_{\alpha\beta}$ is a natural generalization of the critical state model. In the case of structurally isotropic superconductors the tensor describes the conductivity anisotropy in relation to magnetic field direction.

$$\sigma_{\alpha\beta} = \sigma_t(\delta_{\alpha\beta} - b_\alpha b_\beta) + \sigma_l b_\alpha b_\beta$$

*Here $\delta_{\alpha\beta}$ is Kronecker symbol and **b** is the unit vector along the magnetic field **B**.*

$$\sigma_t = \sigma^{(n)}\{1 + \exp\left[\frac{K(T,B) - \frac{|j_t|}{j_{\frac{c}{2},t}(0)}}{\delta}\right]\}, \quad j_{t,\alpha} = (\delta_{\alpha\beta} - b_\alpha b_\beta) j_\beta$$

$$\sigma_l = \sigma^{(n)}\{1 + \exp\left[\frac{K(T,B) - \frac{|j_l|}{j_{\frac{c}{2},l}(0)}}{\delta}\right]\}, \quad j_{l,\alpha} = b_\alpha b_\beta j_\beta$$

Here $j_{\frac{c}{2},l}(0) > j_{\frac{c}{2},t}(0)$, and $K(T,B) = 1 - \frac{T}{T_c} - \frac{|\boldsymbol{B}|}{B_{c2}(0)}$

Parameter δ characterizes the width of a gradual kinetic transition from superconducting to normal state. This set of constitutive equations allows to study unisothermal diffusion of fields and currents in a superconductor at any their orientation. The results accord with Lorentz force hypothesis at not very small anglesbetween magnetic field and current.

16:00- 16:30 Cofee Break

16:30- 18:00 Posters session
Chair: P. Suárez, N. del Valle , A. Álvarez

" Experimental determination of the first penetration field in high-temperature superconductors by mechanical methods"

Jose Luis Perez-Diaz[1], Efren Diez-Jimenez[1], Ignacio Valiente-Blanco[1] and Juan Carlos Garcia-Prada[2]
[1] Departamento de Ingeniería Mecánica. Universidad Carlos III de Madrid. Butarque, 15. E28911 Leganes. Spain.
[2] Instituto Pedro Juan de Lastanosa. Universidad Carlos III de Madrid. Butarque, 15. E28911 Leganes. Spain.

A mechanical method to determine the first penetration field Hp, in a bulk of a hightemperature superconductor has been proposed. It consists on comparing measurement and numerical calculation of forces exerted between a magnet and the superconductor. The deviations between the measured forces and those calculated assuming the superconductor to be at the Meissner State are used to determine the maximum shielding current densities and subsequently the first penetration field. This method mallows comparison with other methods and seems to give good results. As an example, we apply it to an YBa2Cu3O7-x sample. Additionally, we demonstrate that the transition occurs more easily when the magnet is over the borders than over the center.

"High Temperature Superconductor Fault Current Limiter Operating Principle and Results"

S. Nemdili , S. Belkhiat
Department Of Eléctrotechnics, Faculty of Engineering, University Of Sétif, Sétif 19000, Algeria

As today's industry is totally dependent on electrical energy, it requires a continuous flow of electrical energy and blackouts are strictly unacceptable. The most accurate and desired solution would be to limit the fault current during fault or short circuit by installing a FCL in the power systems. High Temperature Superconductor Fault Current Limiters (HTSFCL) use the unique relationship between the resistance and temperature in superconductors to limit potentially damaging short circuit currents after a fault has occurred. The primary advantage of the HTSFCLs is that it offers an optimal solution to the problem of protecting against the short circuit currents because the peak short circuit current is automatically limited as the superconductor makes the transition from a superconducting state to a normal state. HTSFCLs have low impedance in its superconducting state but it increases to a high value during fault. The purpose of this paper is to develop a new model of resistive superconducting fault current limiter, using the MATLAB-SIMULINK. This model is ecessary to analyze the behavior and effectiveness of this type in a power system. So in this paper the demonstration of the High Temperature Superconductor Fault Current Limiter HTSFCL in power systems has been *explained. The MATLAB simulation of the HTSFCL has been done and the results with and without the fault are shown.*

“Modelling Superconductor and Ideal Soft Ferromagnet Hybrids: Application to Levitation”

Sebastia Agramunt-Puig, Nuria Del-Valle, Carles Navau, Alvar Sanchez
Grup d'Electromagnetisme, Departament de Física, Universitat Autònoma de Barcelona 08193 Bellaterra (Barcelona), Catalonia, Spain

Superconducting and ferromagnetic materials appear together in a wide variety of superconducting systems, such as coated conductors with magnetic substrate or superconducting thin films with magnetic inclusions, so it is interesting to analyze the effects of ferromagnetic materials over supercondutors and vice-versa. In this work we present a model that allow us to study a ferromagnetic-superconductor hybrid system composed of a soft ferromagnetic and superconducting bars immersed in an external applied field taking into account the mutual interaction between the elements. The model is based on energy minimization method and assumes infinite susceptibility for the ferromagnet and critical state with Bean's approximation for the superconductor. As an application we calculate the levitation force that exhibit a superconductor over a guideway composed of permanent magnets and a ferromagnet.

“Response of thin superconducting plates to an externally applied magnetic field Response of thin superconducting plates to an externally applied magnetic field”

G. Via, C. Navau, D.-X. Chen, and A. Sanchez
Grup d'Electromagnetisme, Departament de Física,
Universitat Autónoma de Barcelona, 08193 Bellaterra, Barcelona, Spain

Thin superconducting films are a matter of study of particular interest for many applications, in particular those where large diamagnetic susceptibility values and space dependences are desired, as is the case of metamaterials. We present a numerical method to simulate the response of a pair of twin thin superconducting films to an external applied magnetic field within the Critical State Model. The method makes use of the Magnetic Energy Minimization Model (MEM) in order to simulate the magnetic response of the samples via variations in the variable of the system, which in this geometry comes to be the g-function presented by Brandt. Once the profile of g is found, currents, fields, magnetization and susceptibility can be obtained from it. Here we present some of the results for the particular case of two thin rectangular films being one on top of the other and separated by different distances and compare the theoretical results with experiments.

“FEM estimation of the magnetic field in a screened ferromagnetic core for a Resistive-Inductive SFCL”

Alfredo Álvarez, Pilar Suárez, Belén Pérez, José-María Ceballos and Fátima Méndez
Laboratory of Electrical Application of Superconductors. University of Extremadura. Spain

A Resistive-Inductive Superconducting Fault Current Limiter (RI-SFCL) is an inductive limiter which uses the magnetic field in the core after transition to make an in-series resistive limiter transit before reaching the normal critical current. In this way, the whole superconducting element of the resistive part transits suddenly, avoiding the *appearance of hot spots due to the transition in response to current. The core of such a limiter has one or more air-gaps where the resistive elements are located, and in which the magnetic field depends on various design parameters which must be adjusted (screening limit, gap size, current in the inductive coil in series with the resistive element, etc.). This work presents the study of a magnetic core used in the RI-SFCL under construction. In shape, the core consists of a central column and two lateral columns each with half the cross-section of the first. There are two gaps in the lateral columns in which the resistive element operates, and a superconducting screen around the central column on top of which is wound the inductive coil. Two inductive coil models were used, one of copper and the other of superconducting tape. The distribution of the magnetic field in the core and the gaps is examined, and the result of the simulation is verifies by experimental measurements.*

"Modeling of quench in 2G tape using 2D ANSYS model"

Boguslaw Grzesik, Mariusz Stepien
Silesian University of Technology, Gliwice, Poland

FEM analysis of 2G tape is difficult and usually needs 3D calculations with huge computational work. It results from large difference between width and thickness (depth) of tape. This drawback can be used as an advantage in quench analysis.

Authors of this paper present results of calculations of quench in 2G tape. Only 2D model is used for calculations. Because of large width/depth ratio, 2G tape is modeled in plane length-depth while width direction is assumed as infinite. Analysis of quench propagation is considered along the tape length. This approach allows one for reducing essentially time of calculations keeping density of mesh unchanged or improved. The simplification of geometry has little effect on accuracy.

When the length of quench region (in the longitudinal direction) exceeds tape width, results in 2D are the same as in 3D.

The calculations of quench in 2G tape is modeled using ANSYS software. 2D nonlinear transient calculations of coupled electrical thermal model is used. The power law dependence is included as the additional procedure (using ANSYS Parametric Design Language).

The final version of the paper will include description of the tape geometry and its parameters (commercial SuperPower 2G tape is assumed for calculations), description of computational procedure in ANSYS and results of calculations for two different current loads, where quench occurs. The results will be compared to similar those obtained by full 3D model.

"AC losses of an infinitely long superconductor cylinder surrounded by a metallic sheath"

S. Kirsch, J.-F. Fagnard, P. Vanderbemden, B. Vanderheyden
SUPRATECS and Department of Electrical Engineering and Computer Science B28, Sart-Tilman, B-4000 Liège, Belgium

We study the AC losses in a structure composed of an infinitely long superconducting cylinder surrounded by a metallic sheath. The system is subjected to an axial alternating magnetic flux. The AC losses are evaluated locally in each material and compared to the situation where no metal sheath is used. The superconductor region is described by the Bean-Kim model, while the metal is assumed ohmic and non-magnetic. The variation of the magnetic flux in the

superconductor directly affects the eddy currents in the metal sheath. This back-reaction is modelled numerically through a Fourier decomposition of the electrical and magnetic field at the interface between the superconductor and the metal. The resulting losses are evaluated as a function of the frequency and the amplitude of the source field.

"Transient response of HTS generator"

Victor M.R. Zermeno[1], Asger B. Abrahamsen[2], Nenad Mijatovic[3], Bogi B. Jensen3, Mads P. Sørensen[1].
[1]Department of Mathematics, Technical University of Denmark, Kgs. Lyngby, Denmark.
[2]Department of Wind Energy, Technical University of Denmark, Roskilde, Denmark.
[3]Department of Electrical Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark.

Modeling and simulation of hysteresis losses in the HTS windings of rotating machinery during transient operation is a very challenging task. It requires considering a system that spans spatially several orders of magnitude: from the micrometer thick superconducting layers in the coated conductors, to the actual generator cross section in the order of decimeters or even meters. In this work, we present a bottom-up model of a generator with superconducting rotor windings. The strategy relies on a two-stage segregated model. In a first step, the electromagnetic response of a generator under transient operation is computed. A second step uses an anisotropic bulk to model the HTS windings in the rotor of the generator. Transient response, including ramp-up of rotor coils, load connection and change were computed. This allowed addressing several important design and performance issues such as critical current of the superconducting coils, electric load change rate, cryostat design and identification of quench-prone regions.

"A homogenization technique to calculate AC losses in HTS stacks"

Victor M.R. Zermeno[1], Asger B. Abrahamsen2, Nenad Mijatovic[3], Bogi B. Jensen[3], Mads P. Sørensen[1].
[1]Department of Mathematics, Technical University of Denmark, Kgs. Lyngby, Denmark.
[2]Department of Wind Energy, Technical University of Denmark, Roskilde, Denmark.
[3]Department of Electrical Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark.

Calculating hysteretic losses in HTS stacks and coils can become a challenging task when considering large scale devices such as motors, generators, magnets or Roebel cables. With the growing number of conductors in stacks or turns in coils, the computational time required to perform calculations rises accordingly. In this work, a homogenization method to model stacks of HTS coated conductors is presented. Both cases of transport current and applied magnetic field are considered. The underlying idea is to find an equivalent bulk model that "washes out" the internal layers of the stack while keeping its overall electromagnetic behavior. Our work extends the homogeneous-medium anisotropic bulk model originally presented by Clem et al. and later refined by Yuan et al., and Prigozhin and Sokolovsky. However, unlike these previous works, ours considers a power law E-J relationship, hence allowing the current density to achieve overcritical values. This issue is of key importance when considering the transient response of devices or non-harmonic oscillations. The proposed method is validated against full 2-D simulations taking into account the actual structure of the stacks to the micrometer scale. A computational speedup factor of up to 2 orders of magnitude was achieved without a significant compromise in accuracy.

"Electrical-thermal coupled model of second generation HTS cables for application in power system simulations"

Gerard Del-Rosario-Calaf[1], Joaquim Lloberas-Valls[1], Andreas Sumper[1,2], Xavier Granados[3], Roberto Villafáfila-Robles [2]

[1] Catalonia Institute for Energy Research, IREC
Jardins de les Dones de Negre 1, 08930 Sant Adrià de Besòs (Barcelona), Spain
[2]CITCEA-UPC, Universitat Politècnica de Catalunya, Escola Universitària d'Enginyeria Tècnica Industrial de Barcelona, C/ Comte d'Urgell, 187; 08036 Barcelona, Spain
[3] ICMAB-CSIC, Campus UAB, 08193, Cerdanyola del Vallès (Barcelona), Spain

Power system simulation software packages usually use equivalent pi circuits for modeling of conventional power cables, which take into account resistive losses along the cable. A similar approach is presented in this work, in which non-linear behavior of electrical losses of second generation HTS cables is modeled as a current and temperature-dependant variable resistance and included in a pi circuit. Current variations due to grid operation or disturbances produce changes in the heat dissipation within the cable and this fact is taken into account to recalculate the temperatures of cable components, including HTS tapes and conductor layers. Present temperature values are used every time step to update the resistance value prior to the calculation of new cable current values in the simulator. In this stage of the work, thermal dissipation in HTS and conductor layers is assumed as a known input of the model but it is aimed that this heat generation will be coupled with grid current values in order to provide a suitable model for power system simulations in the future.
Acknowledgement: We would like to acknowledge the encouragement from colleagues from Catalonia Institute for Energy Research (IREC), ICMAB-CSIC and CITCEA-UPC. The contributions from the ENDESA-NOVARE project "Supercable", MICINN MAT2008-01022 , "Nanoselect" Consolider, and Xermae have also been appreciated.

21:00- 23:00 Gala Dinner

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April 13th

09:00-11:00 Parallel Discussion Meetings, Àgora, Beta & Gamma Halls

Topics Industrial requirements, Method improvements, Fundamental problems (can be changed during the Workshop)

11:00-11:30 Cofee Break

11:30- 13:00 Discussion Summaries, Àgora Hall

13:00-14:30 Lunch

14:30-16:30 Workshop Summary & General comments, Àgora Hall

- Next workshop
- Steering Comitee report
- Concluding remarks
- Closing